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MECHANICAL ACTIVATED SLUDGE PLANT
AT BAER FIELD, INDIANA

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A STUDY OF THE OPERATION OF
THE MECHANICAL ACTIVATED
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AT BAER FIELD, INDIANA

BY

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INTRODUCTION

This station has been interested in studying small so-called package sewage treatment plants with the purpose of determining their efficiency and suitability for the treatment of sewage from small towns. It was learned from the Fifth Service Command that difficulties were being experienced with the operation of a small mechanical activated sludge plant at Baer Field. Arrangements were therefore initiated for this station to make a study of the plant in the belief that such a program would be of mutual benefit to the Army and the Public Health Service. A preliminary survey of the operation of the plant at Baer Field was made in November, 1944. This survey indicated an oxygen deficiency in the mechanical aerators due to the strong sewage being applied. Major Arthur H. Wedge Post Engineer at Baer Field had already recommended the installation of additional diffused air aeration facilities and it was agreed that a careful study of plant operation should be postponed until after such additions were made. These facilities were completed late in the summer of 1945. Accordingly with the co-operation of Major Wedge arrangements were completed for the study of plant operation in September. The U. S. Public Health Service trailer laboratory was brought to Baer Field on September 19 and a study was made until October 4, 1945 to determine performance efficiency of the plant and the causes of difficulties that were encountered.

PLANT DESCRIPTION

The plant is a small activated sludge plant with mechanical aerators of the downdraft type. Sewage flows to and through the plant by gravity with no pumping required except for sludge. The plant was designed for an assumed flow of 245 000 gallons per day based on 70 gallons per capita for a population of 3,500.

The sewage plant is located at the N.E. corner of the reservation, not far from the barrack area of the field, and all sewage reaches the plant in a short time. The incoming sewage is passed through a Chicago Pump Company comminutor and ground alum is added to the sewage intermittently before it reaches the primary settling tank.

The primary tank is rectangular, 40 ft. long by 8 ft. wide, with an average water depth of 8.25 ft. and is equipped with Jeffrey sludge removal equipment. The sludge hopper is at the inlet end and the return run of the conveyor flights serve to skim the surface of the tank. Due to the fact that the primary tank effluent channel and the final tank effluent pipe are built into the top of one wall and extend 12" into the tank, the flights are unable to sweep a strip of the bottom 12" wide by about 34 ft. long.

There are four aerator tanks, each 19 ft. square with a water depth of 8.75 ft., equipped with American Well Works downdraft aerators powered with 3 HP motors. Diffused air

is also applied to each of the aerators through Chicago Pump Company swing tube diffusers. The air is supplied by four Nash Hytor compressors, model MD-671, operating against a 3-lb. head at 1750 R.P.M. It is estimated from rating curves that these units should deliver 22 cu. ft. of free air per minute each. No meter is available for measuring the delivery of air to the tanks. Return activated sludge is added to the primary effluent just before it enters the aerators, and the aerators are operated in two parallel sets of two tanks in series. Excess activated sludge is wasted to the primary influent during the night shifts.

There are two rectangular final settling tanks operated in parallel. These tanks are 40 ft. long by 8 ft. wide, with an average water depth of 7.0 ft. The sludge hoppers are at the inlet end, and the return run of the sludge flights are used for skimming. The final effluent is chlorinated just before it reaches the chamber containing a 90° V-notch weir used to measure the sewage flow.

Sludge from the primary tank is pumped to one of the two heated digesters. These units are equipped with floating covers and are 26 ft. in diameter. Gas is collected and burned in a hot water boiler which serves to heat the digesters and the operation building. Excess gas is burned in a burner nearby. The digested sludge is pumped to underdrained, open beds for drying.

DESCRIPTION OF PLANT UNITS

Screen

Chicago Pump Company comminutor.

Alum Feeder

Syntron vibratory dry feeder.

Primary Settling Tank

Rectangular tank 40' x 8' x 8.25' average water depth, equipped with Jeffrey sludge removal equipment, the return run of flights serving to skim the tank. Sludge hopper at inlet end. Due to location of primary and final effluent conduits, the sludge conveyor flights miss a strip about 12" wide on one side of the bottom.

Capacity: 2640 cu. ft. or 19,750 gal.

Weir length: 24.6 ft.

Aerators

Rectangular tanks 19' x 19' x 8.75 ft. water depth.

Four tanks equipped with American Well Works mechanical aerators (downdraft) driven by 3 HP motors. Diffused air is supplied to each tank through Chicago Pump Company swing-type diffusers. The air is furnished by four Nash Hytor compressors, MD-671, each driven by a 2 HP motor at 1720 R.P.M. and pumping against a head of 2.75 to 3.0-lbs./sq.in. Flow is divided and each portion passes through 2 aerators in series.

Capacity: (total) 12,650 cu.ft. or 94,600 gal.

Diffused air delivery: $22 \times 4 = 88$ cu.ft.free air/min.

(From Nash Engineering Co. catalog)

Final Settling Tanks - 2 tanks in parallel

Rectangular tanks 40' x 8' x 7.0' average water depth.

Two tanks in parallel, equipped with Jeffrey sludge removal equipment, return run of flights serving to skim the tank. Sludge hopper at inlet end. Each tank has 55.0 ft. of effluent weir.

Capacity (both tanks): 4,490 cu.ft. or 33,600 gal.

Weir length (both tanks): 110.0 lineal feet.

Digesters

Circular heated digesters with floating covers.

Two digesters 26.0' dia. Water depth above hopper 9.25 ft. at low water level and 15.25 ft. at high water level. Hoppers are 4.33 ft. deep to theoretical point. Each digester has 319 ft. of 2" pipe heating coils arranged in a 4-coil helix from 2 ft. to 6 ft. above the hopper.

Capacity: Low water level: 5,675 cu.ft. or 42,500 gal.

High " " 8,855 " " " 66,400 "

FLOW MEASUREMENT DEVICES

The only flow measurement device provided is a 90° V-notch weir on the final effluent for measuring the sewage flow. The weir is set in a concrete chamber about 4' x 6' and the head is transmitted through about 75' of 3/4 inch pipe to a float tube and recorded on a Bailey recorder registering the head in inches and tenths and the flow rate in thousand gallons per day. No totalizer was used. A water-level gauge has been installed on the wall of the weir chamber in the pipe gallery with a head scale in inches and tenths mounted on the wall behind it. On September 20, 1945, this recorder was found to be recording heads two inches greater than those found by direct measurement in the weir chamber. The water-level gauge was found to give readings 0.3" lower than the direct measurements in the weir chamber. It is believed that readings on the tube gauge corrected by plus 0.3" will give the most accurate approximation of the flow if read every hour or half hour.

No means were provided for measuring the amount of activated sludge returned or wasted. A 9" end-contracted rectangular weir was installed in the diversion box on Sept. 21 to measure the total sludge returned and wasted. A gauge reading in tenths and hundredths of feet was provided to measure the head on this weir and a rating table has been computed.

No meter for measuring the diffused air provided to the aeration tanks is available. An estimate of this diffused air has been made from a capacity chart for this model of compressor. No electrical meters were installed, so no measurement of electrical consumption can be made. It was noted that the rated capacity of the motors installed for aeration (aerators and compressors) totals 20 HP.

A study of a typical weekday flow chart (0800 hours Sept. 19 to 0800 Sept. 20) shows that the heavy day flow is from 0800 to 2300 with the maximum from 1630 to 2000. The flow drops gradually from 2300 to 0300 and the minimum night flow is from 0300 to 0500. The flow increases gradually at 0600, and rises rapidly from 0700 to 0800. The maximum and minimum rates of flow were as follows:

Flow readings by recorder - maximum 0.700 M.G.D.

minimum 0.200 "

Estimated corrected reading - maximum 0.330 M.G.D.

minimum 0.040 "

The hydraulic data obtained during the study including the average rates of sewage flow for various periods of the day, the rate of sludge return, the detention periods in the primary, aeration and final tanks, and the weir overflow rates for the primary and secondary tanks are given in tables 1 to 4.

COLLECTION OF SAMPLES

Samples were collected every thirty minutes from 0700 until 2300 and composited according to flow. In compositing the samples no adjustment was made for detention time in any of the units of the plant. The 18-hour composite samples collected included the raw sewage, the primary effluent and the final effluent. All mixed liquor samples collected for settling tests or for the determination of oxygen utilization rates and also all samples collected for dissolved oxygen determination were, necessarily grab samples.

ANALYTICAL PROCEDURES

With the exception of the methods for the determination of dissolved oxygen, all analytical determinations were made in accordance with "Standard Methods for the Examination of Water and Sewage" published by the American Public Health Association. All plant effluent dissolved oxygen determinations were made by the short Winkler technique using sodium azide in the alkaline iodide solution (1) (2) to destroy and prevent interference by nitrites. The dissolved oxygen determinations in the mixed liquor were made using the special sulfamic acid copper sulfate inhibitor according to the technique of Ruchhoft and Placak (3); both above procedures for dissolved oxygen are being included in the forthcoming edition of Standard Methods.

The method for determining the rate of oxygen utilization (4) in the mixed liquor is one that has been developed at this station. This oxygen utilization study had a special purpose outside the general scope of this study and will not be reported on in detail here.

ANALYTICAL RESULTS

The basic analytical results that were obtained during the study are given in tables 5, 6 and 7 for the raw sewage, primary effluent and final effluent respectively. The data on the raw sewage show an average B.O.D. of 405 P.P.M. On October 1 there was considerable rain with a 24-hour sewage flow of more than double the average daily flow for the period of the study. The B.O.D. of the sewage on this day dropped to 161 P.P.M. and a corresponding drop was indicated in all other determinations. The suspended solids averaged 236 P.P.M. with an average volatile solids content of about 86.0%. The raw sewage averaged 51.0 P.P.M. of Kjeldahl nitrogen and 34.7 P.P.M. of free ammonia nitrogen. These latter values are of the same order of magnitude as for Kjeldahl nitrogen and free ammonia found at Fort Sheridan and the two Great Lakes Naval Training Station sewage plants. The pH of the raw sewage varied from 7.1 to 7.8 which is normal. These analyses indicate that the Baer Field sewage is a fairly typical, strong sewage from a military camp. Army experience has shown that the per capita B.O.D. contribution for military camps is considerably greater than in domestic sewage.

PRIMARY TANK PERFORMANCE

On the basis of the data given in tables 5, 6 and 7 the percentage removals obtained by primary treatment only and for the whole plant were calculated and are given in table 8. This table shows that the primary tank gave practically no removal of free ammonia or Kjeldahl nitrogen, gave an average of only 19.9% reduction in B.O.D. and only 29.5% reduction in suspended solids. As the B.O.D. removal at 16 Army plants by primary settling varied from about 20 to 50 per cent for annual observation periods, it must be concluded that the B.O.D. removed by the primary tank at Baer Field was decidedly below par. The same group of Army plants showed an average suspended solids removal of about 45 to 65% compared to only 29.5% for Baer Field. A partial explanation for the poor performance of the primary tank is given by the detention period for the period of sampling as shown in table 2. These data show that the detention period in the primary tank varied from 0.63 to 2.22 hours with a mean of 1.48 hours. These short detention periods and the additional fact that the flights were unable to sweep the entire width of the bottom of the tank probably caused the very poor performance of this tank.

OVER-ALL PLANT PERFORMANCE

Since the primary tank did not perform on the basis of the assumptions usually made in design, the aeration tanks received a much greater load than expected. Consequently, the over-all plant performance was also poor as shown in table 8. Only 85.1% of the B.O.D. was removed, leaving a B.O.D. of 34 to 78 P.P.M. in the effluent. The plant removed an average of only 63.2% of the suspended solids, and the effluent carried from 42 to 106 P.P.M. of suspended matter. Table 9 shows the suspended solids, ash, per cent ash and sludge index for the mixed liquor and the return sludge. It will be noticed that 1300 to 1570 P.P.M. of suspended solids were carried in the mixed liquor. The ash content of this sludge averaged about 12 to 14% which is rather low. Considering the low ash content, the mixed liquor sludge index of 90.6 to 123 was not as high as might be expected and the sludge could not be called a badly bulking sludge. The poor showing of the plant must be partly attributed to the design and performance of the secondary settling tanks which provided settling periods varying from 0.84 to 1.72 hours (average 1.43). This is particularly true for the poor showing in suspended solids removal.

Considering the low mixed liquor suspended solids that could be carried, the comparatively short aeration period (which averaged 4.01 hours during the sampling period and

varied from 2.27 to 4.84 hours), and the B.O.D. load, it is remarkable that the plant was able to average 85.1 per cent B.O.D. removal. The quantities of B.O.D. and suspended solids in pounds in the raw sewage primary effluent and final effluent are given in table 11. An average of 1001 pounds of B.O.D. per day was applied to the aeration tanks, which is equivalent to 79.2 pounds per 1000 cu.ft. of aeration tank volume. The B.O.D. load for large municipal plants varies from about 13 to 38 pounds per 1000 cu.ft. of aeration tank volume. To conform to standard practice for domestic sewage at least double the present aeration tank capacity should have been provided at Baer Field.

CORRELATION OF APPLIED LOAD WITH REMOVAL

Although the data were limited, a study was made of the correlation between the quantity of B.O.D. applied to the aeration tanks and the quantity of B.O.D. removed in pounds. These data are shown plotted in Figure 1 with the determined curve of best fit. This study gave a correlation coefficient of plus 0.92 between these variables, which checks well with the direct correlation suggested by the distribution of the data on the curve in Figure 1. A similar correlation study between B.O.D. per 100 pounds of suspended solids in the aeration tanks and the pounds of B.O.D. removed was made, which indicated no better correlation than shown in figure 1.

The B.O.D. load per day expressed as pounds per 100 pounds of suspended solids in the aeration tank mixed liquor varied from 500 to 825 during this study. A correlation study between the pounds of suspended solids applied to the aeration tanks and the pounds removed gave a correlation coefficient of plus 0.82. This poorer correlation between load and removal in suspended solids may be explained by the poor operation of the final tanks. Much poorer correlation was found between the quantity of Kjeldahl nitrogen applied and the quantity removed for this short period study.

DISSOLVED OXYGEN STUDIES

The dissolved oxygen results obtained on mixed liquor and plant effluent are shown in table 10. It will be noted that an average of about 4.5 P.P.M. of dissolved oxygen was maintained in the final effluent. On the other hand, mean D. O. values of only 0.44 and 0.89 P.P.M. were obtained by the technique previously mentioned in tanks 1 and 3 respectively. It was observed in the oxygen determinations that the iodine was rapidly lost due to high iodine demands of the clarified mixed liquor. The D.O. values in tanks 1 and 3 are therefore considered too low and only poor approximations of the dissolved oxygen actually present. Although this dissolved oxygen technique has given good results in mixed liquor at other plants, it was unsatisfactory for conditions found at Beer Field.

Since the mean D.O. in the effluent was found to be 4.58 P.P.M., the mixed liquor in the two effluent tanks must have contained at least this concentration. Consequently it can be concluded that the addition of the Chicago Pump Co. swing type aerators has been effective in maintaining a sufficient oxygen supply in the mixed liquor even with the overloaded aeration tanks. It is interesting to note that during this study about 0.42 cu.ft. of air per gallon of sewage was used on the basis of the rated output of the compressors. On this same basis 10.5 pounds of B.O.D. were treated per 1000 cu.ft. of diffused air. As this is almost 5 times the quantity of B.O.D. applied per 1000 cu.ft. of diffused air in most large municipal plants it can be surmised that the additional aeration capacity of the mechanical aerators is also used and needed to get the performance observed at this plant.

OXYGEN UTILIZATION RATES

A study of the rates of oxygen utilization by the method previously described (4) in mixed liquor from the aeration tanks was made and the data obtained are presented in table 13. These data confirmed the observations previously made at Ann Arbor, Michigan, and at the Great Lakes Naval Training Station Green Bay Plant, that there was a diurnal variation in the rate of oxygen used in the mixed liquor depending upon

the quantity and strength of sewage arriving at the plant. The rates of oxygen utilization at Baer Field were similar to but somewhat higher than those observed at the above-mentioned plants. The most significant observation was the fact that late in the afternoon (5:00 to 6:00 P.M.) the rates of oxygen utilization in the mixed liquor effluent reached 42 to 44 P.P.M. per hour and exceeded those rates observed for the mixed liquor influent before 9:00 A.M. These values for the mixed liquor effluent are considered too high and are suggested as indicating that the aeration period given the strong afternoon sewage, was inadequate at this plant.

SUMMARY

The sewage flow, as calculated from weir readings, varied from 0.04 to 0.33 M.G.D. during the period of this survey. These values were considerably below the flow readings given by the recorder which were in error. The raw sewage showed an average suspended solids content of 236 P.P.M. and an average 5-day B.O.D. of 405 P.P.M. The primary tank provided a detention period of 1.5 hours for the average flow and a detention period of only 0.63 hours at maximum flow. An average reduction of only 19.9% in 5-day B.O.D. and only 29.5% in suspended solids was obtained by the primary tank. The short detention period plus a tank design which prevented the flights from sweeping the entire width of the bottom probably contributed to the poor performance of the primary tank.

The aeration tanks received a greater B.O.D. and suspended solids load than was assumed in design. In fact an average of 79.2 lbs. of 5-day B.O.D. per 1000 cu.ft. of aeration tank volume was applied to these tanks. This is double the B.O.D. load applied in standard practice at municipal activated sludge plants. The aeration tanks were operated with 1300 to 1570 P.P.M. of suspended solids in the mixed liquor and from 73 to 81 per cent of sludge return. The sludge index varied between 90.6 and 123. This was considered a fair sludge which is not too difficult to settle. The original mechanical aerators were entirely inadequate for the oxygen requirements of mixed liquor, but with the supplemental diffused air an adequate oxygen supply was indicated by the dissolved oxygen determinations. The aeration period averaged 4.01 hours and the oxygen utilization tests on the mixed liquor effluent indicated that this period was definitely inadequate for the sewage being treated.

The plant effluent contained an average of 81 P.P.M. of suspended solids and 54.4 P.P.M. of B.O.D. The plant gave an over-all removal of 95.1% in B.O.D. and only 63.2% in suspended solids. This poor performance must be attributed to the overloaded condition in a plant which was not too well designed. In conclusion we wish to compliment the operators on the excellence of the results that were obtained considering the sewage load and plant facilities.

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